Industrial Technologies Program

Development of Ultrananocrystalline Diamond (UNCD) Coatings

Ultrananocrystalline Diamond (UNCD) Coatings on Pump Seals can Impact all of the IOF Industries

This materials project, based on UNCD thin films that were conceived and patented at Argonne National Laboratory, will have a major impact on many of the Industries of the Future (IOFs). Prior work at Argonne demonstrated that UNCD thin films can be grown on a variety of substrates by using an emerging microwave plasma chemical vapor deposition system. The UNCD thin films exhibit a unique microstructure that provides superior mechanical (high hardness and extreme fracture toughness), tribological (low coefficient of friction), chemical (inertness to chemical attack), and electronic (wide range of conductivity) properties. To apply this technology commercially, work is needed on improving plasma uniformity and automating the diamond seeding process to produce UNCD layers on large-area substrates with uniform thickness and microstructure. The project involves an interdisciplinary effort between Argonne, John Crane, Inc., and Advanced Diamond Technologies, Inc. which provides the fundamental, applied, and technological base for this project. As the scientific and technological base is developed for UNCD, more applications will be identified and demonstrated for proof of concept. Further development of UNCD for those applications would continue under separate projects.

The first application identified for UNCD thin films is on seals for multipurpose mechanical pumps. In prior work, growing UNCD using conventional microwave plasma technology has been demonstrated on a 2-inch seal, which showed an undetectable wear rate and a sixfold reduction in frictional energy loss in a bench-scale test. To produce larger seals in production quantities, growing UNCD coatings on multiple seals at one time using an emerging microwave plasma reactor technology needs to be demonstrated.

Microwave Plasma Reactor at Argonne National Laboratory

Benefits for Our Industry and Our Nation

- *Developing the technological base to use UNCD thin films as low-friction, and corrosion-and wear resistant coatings would optimize energy efficiency in a wide range of mechanical systems.*
- *The development of UNCD-processed seals may result in a sixfold decrease in pump shaft frictional torque, which translates into a reduction of 80% in frictional energy loss.*
- *A particular application such as UNCD-processed seals for the production of more energy-efficient (up to 20% energy saving), cleaner, environmentally benign multipurpose mechanical pumps (for pumping fluid) is to be evaluated.*

Applications in Our Nation's Industry

There are many rotating and/or sliding components in mechanical systems, such as shaft seals used in multipurpose pumps, bearings, and gears, that are critical to the operation of simple or complex systems in many IOF industries:

- *Agriculture*
- *Aluminum*
- *Chemicals*
- *Forest Products*
- *Glass*
- *Metalcasting*
- *Mining*
- *Petroleum*
- *Steel Industries*

Project Description

The goal of this project is to develop UNCD films for use as wear-resistant, low-friction coatings for SiC multipurpose mechanical pump seals. Such coatings will be important in all of the IOFs. A specific application, fluid pumping, has been identified to take advantage of the unique materials properties of UNCD films. Pumping high-velocity, possibly corrosive fluids at high pressures forms an important process step for many of the IOFs. While fluid pumping is emphasized in this project, it is important to note that the development of corrosive-resistant, wear-resistant, low-friction coatings will have a much broader useful impact.

Barriers

Major barriers to be overcome are:

- Obtaining uniform nucleation and growth of UNCD with both smooth films and good adhesion.
- A scale-up in the UNCD deposition process to a system that would allow for batch coating of multiple seals.
- Limited seal testing facilities.
- Lack of a commercialization protocol.

Pathways

Much research and numerous tests have resulted in the development of the proper seeding technique. This seeding allows for a high nucleation density which leads to a dense, continuous, smooth film. The challenge of good adhesion has also been remedied. Work is underway to commission and install an IPLAS 11-inch microwave plasma CVD System. The first unit of its kind in the world, this plasma system will allow for batch coatings of multiple 2-inch seals. A typical pump seal can last for years, making lifetime testing of seals a difficult procedure. John Crane, the world's largest manufacturer of mechanical seals, has developed a test that mimics the harsh conditions in a chemical process pump. This 100-hour test simulates 2 years of extreme use.

Milestones

- Consistently produce UNCD-coated seals which contain smooth films and good adhesion
- Commission and optimize an 11-inch IPLAS system; demonstrate UNCD batch coating on multiple 2-inch seals using this system
- Run the simulated long-term pump tests; verify the results and advantages of UNCD pump seals

Commercialization

Advanced Diamond Technologies, Inc. (ADT) was formed by ANL to be the commercialization vehicle for UNCD. ADT has developed partnerships and entered into collaborations with leading companies which, like project partner John Crane, Inc., will be marketing partners of ADT. Through ADT, a mechanism exists for rapid and broad deployment of UNCD technology to a variety of the IOFs, as well as other industries.

It is envisioned that Crane will provide engineered seals to ADT, and ADT will deposit the UNCD thin films. With this business arrangement, ADT is free to focus on its competency which is the production of large area UNCD coatings, while benefiting from the unmatched marketing and distribution capabilities of Crane worldwide. This arrangement was optimized around speed to market.

ADT has done the financial modeling to justify that the UNCD platform can be used to provide cost-effective and market-ready UNCD seals. ADT was judged "Most Promising Company" at the Nanotechnology Venture Fair in La Jolla, California in September, 2002.

The large area plasma system described here was a winner of an R&D 100 award in 2003.

Project Partners

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